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ACID MINE DRAINAGE AND STRIP MINES

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INTERDISCIPLINARY APPLICATION AND INTERPRETATION OF ERTS DATA WITHIN THE SUSQUEHANNA RIVER BASIN

Resource Inventory, Land Use, and Pollution

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The objective of this study is to assess the usefulness of ERTS-1 data, particularly multispectral scanner (MSS) data, for (1) monitoring the areal extent of stripping for coal, (2) detecting areas adversely affected by acid mine drainage, and (3) determining the effectiveness of reclamation and abatement procedures of stripped areas.

Procedure

An area along the West Branch of the Susquehanna River was chosen for the initial tests of the present study because it contains old stripped areas, new stripped areas, and numerous examples of acid mine drainage and related effects associated with the mining of bituminous coal in Pennsylvania. In addition, detailed ground-based geological and geophysical observations are available for a portion of the area near Kylertown. Aircraft underflight data from U2 and C130 flights are available for portions of the test area as well. These additional data provide important ground truth for evaluating the results obtained from digital processing of ERTS-1 multispectral scanner (MSS) tapes.

The MSS digital data tape for the September 6, 1972 pass over Pennsylvania (scene 1045-15240) was used for computer analysis of the area. Even though data from channel 6 were too poor to be usable, remarkably good results were obtained by using data from channels 4, 5, and 7 simultaneously to identify the characteristic features of stripmined areas and acid mine drainage effects.

The data processing consisted first of subsetting the original data tape to obtain a working digital tape covering a test area approximately 20 x 20 miles square located in Clearfield County, on the West Branch of the Susquehanna River, and extending south from Karthus to Philipsburg. Using a series of computer programs developed by Borden and other members of the ORSER staff (see ORSER-SSEL Technical Report 10-73), the test area tape was analyzed. First we located areas of both uniformity and high

spatial contrast. These data alone defined the approximate boundaries of some stripped areas and showed distinctive features such as the river and Interstate 80. Unambiguous correlations with conventional map features could then be made. We found that application of the cluster analysis program developed by Turner (DCLUS) provided the best definition of stripped areas as well as other features in the test area. Basically, this program groups the data points into clusters each of which has a characteristic spectral response. No prior knowledge about the spectral response is required in this mode of operation, although predetermined training areas can be used as a program option. Not only was it possible to identify stripped areas unambiguously, but additional subclassifications were found to represent real differences in conditions, such as trenched areas, recent workings, and partly vegetated peripheral zones.

Several portions of the Susquehanna River itself were classified in the same category as strip mines. While surprising at first, this finding is now believed to represent refuse from nearby stripping that was dumped along the banks, in which case the classification was proper. Other areas along the river were placed in the same category as areas of dying or dead vegetation caused by acid mine drainage elsewhere in the test area. The inference that the Susquehanna River in this area is highly polluted by acid mine drainage is correct[1].

Especially detailed analysis was carried out for a small area around Kylertown. Subdivisions of the stripped areas that were distinctly classified in this test area were: trenched areas, backfills, and new stripping or areas cleared for future stripping operations. These subdivisions are shown in Figure 1. Areas of dying or dead vegetation caused by acid drainage from these mines were distinctly classified by cluster analysis and were spatially located correctly, including a very small one that has been studied extensively with ground-based methods.

A U2 photograph of the area covered by Figure 1 is shown in Figure 2, and Table 1 summarizes the cluster analysis results for the

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[1]Appalachian Regional Commission (1969) "Acid Mine Drainage in Appalachia," Appalachian Regional Commission, 1666 Connecticut Avenue, Washington, D. C. 20235.

BLOCK SPECIFICATIONS

BEGINNING LINE	2137
ENDING LINE	2170
BEGINNING ELEMENT	635
ENDING ELEMENT	690
LINE INCREMENT	1
ELEMENT INCREMENT	1

0 1 km
Approximate Scale

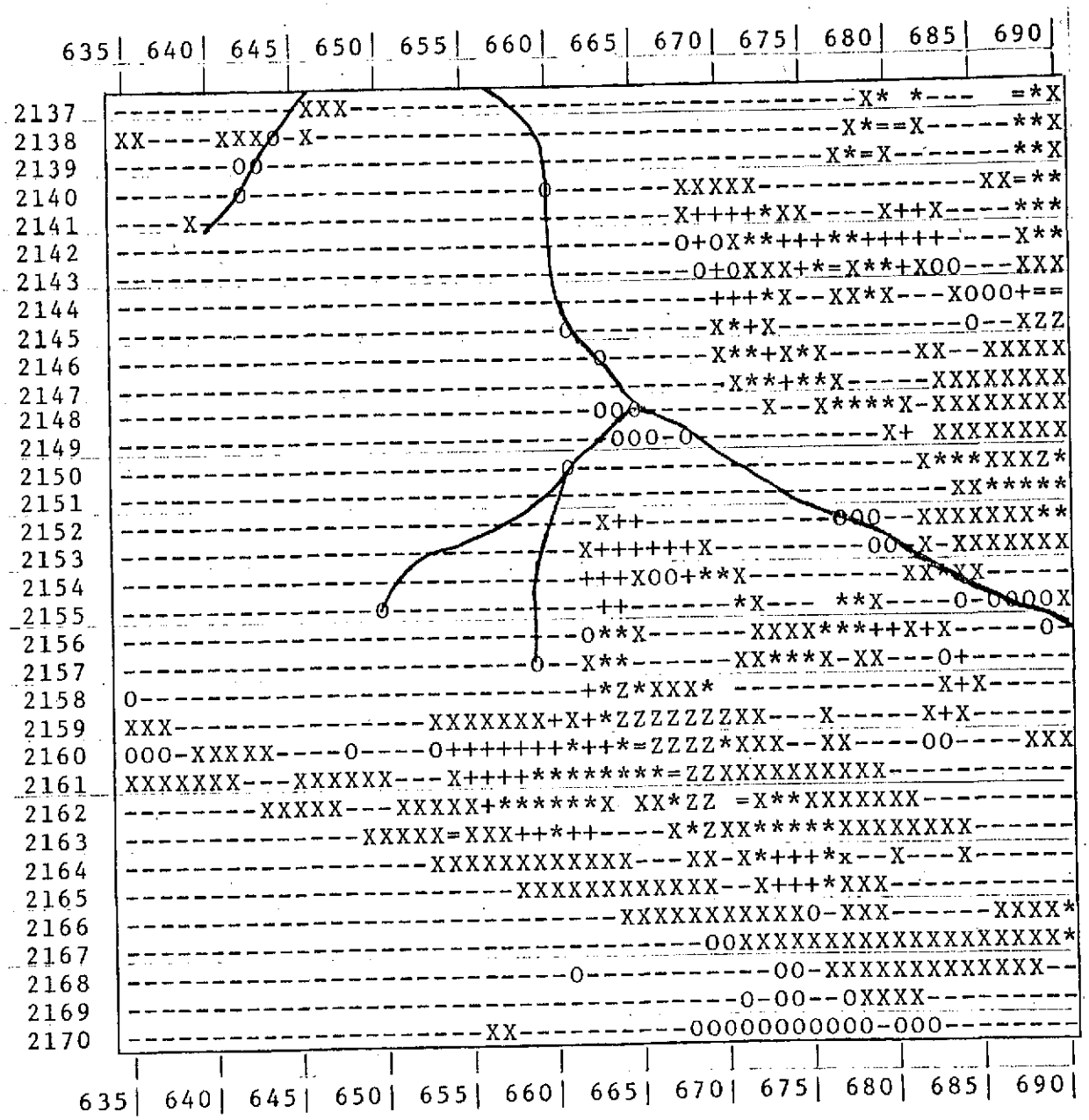

Figure 1: Classification map for the Kylertown area. Symbols are defined in Table 1.

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Figure 2: U2 photograph of the Kylertown test area. (Flight 72-094, sensor 14, frame 72511; approximate scale:

Table 1 : Spectral Responses from Cluster Analysis of the Kylertown Area

Categories	Number	Symbol	Channels 4	5	7	Percent Area
Forests	1	-	23.43	14.29	24.42	68
Open fields	2	X	27.20	21.37	21.27	17
Trenches (strip mine)	3	+	30.50	25.72	11.00	4
Backfills (strip mine)	4	*	32.89	30.67	14.56	5
Affected by acid mine drainage	5	0	24.67	15.67	14.33	4
New stripping	6	=	38.00	41.00	19.00	1
Cleared for future stripping	7	Z	46.00	52.33	23.67	1

Table 2 : Distances of Separation for Categories from the Kylertown Area

Category number and symbol		1 (-)	2 (X)	3 (+)	4 (*)	5 (0)	6 (=)	7 (Z)
1	(-)	0.0	8.62	19.00	21.33	10.25	30.91	44.24
2	(X)	8.62	0.0	11.63	12.80	9.33	22.52	36.30
3	(+)	19.00	11.63	0.0	6.54	12.09	18.81	33.30
4	(*)	21.33	12.80	6.54	0.0	17.11	12.36	26.91
5	(0)	10.25	9.33	12.09	17.11	0.0	29.01	43.44
6	(=)	30.91	22.52	18.81	12.36	29.01	0.0	14.64
7	(Z)	44.24	36.30	33.30	26.91	43.44	14.64	0.0

area. From examining U2 and C130 underflight photography we were able to identify the categories of features found by the cluster analysis. These are listed in the first column of Table 1 . The degree to which these categories are separated is indicated in Table 2 , where the distances of separation among the clusters are given. The smaller the distance between two categories the more similar they are. For example the subclassifications 3 and 4 that differentiate trenched portions of stripped areas from backfills have a relatively small distance of separation and are generally similar in spectral response, as can be seen from the values on Table 2 .

The digital processing used here has the further advantage that not only are features correctly classified but the total area affected by stripping can be routinely calculated from the estimates of the total area represented by each category output by the cluster analysis program. For example, we found that strip mines cover approximately 20 percent of the test area around the Susquehanna River and about 11 percent of the area around Kylertown. The last column of Table 1 gives the percentage area represented by each category for Kylertown.

The spectral response was found to be quite similar for all stripped areas within the test area. Presently we are using the characteristic spectral response of this area to classify adjacent areas with the objective of eventually mapping and classifying accurately the stripped areas of Pennsylvania and the areas affected by acid mine drainage. We also anticipate repeating the analysis of this area for different seasons to ascertain the optimum conditions for mapping acid mine drainage effects.

While visual examination of the ERTS-1 imagery reveals the location of the larger strip mines, it is not possible to distinguish visually the subclassifications and details found by the digital analysis described above. Areas affected by acid mine drainage cannot be discerned or identified by visual analysis of the ERTS imagery. Therefore, digital processing is required to extract adequate information on the details of strip mining and acid mine drainage.

In order to check the validity of the digital processing results for the Kylertown area, photographs from the C130 flights of July 1972

were analyzed; in particular the 9" x 9" visible color and color infrared frames (numbers 139 and 140 of Roll 39, and 150 and 151 of Roll 40, respectively) were studied. The features classified in Table 1 were distinct in these photographs. From analysis of the underflight images there is evidence of stress on vegetation associated with the areas designated in Table 1 as affected by acid mine drainage. This correlation of underflight evidence and digital classification is of particular importance because stress caused by acid mine drainage cannot be identified by visual analysis of ERTS-1 imagery. This vegetative stress was further confirmed by field checks in the Kylertown area. Both C130 and U2 underflight data were used to verify the spatial extent of the areas classified presently as stripped. There is considerable difference between the areas of stripping indicated on the USGS 7 1/2 minute quadrangle maps of 1959 and those from ERTS-1 digital analysis. Our results agree closely with the 1971 topographic maps of this area on which areas of recent stripping are included.

Conclusions

1. ERTS-1 MSS data can be used with appropriate digital processing programs to map the extent and type of stripping that exists at the present time, including subclassifications of each stripped area.

2. Based on the preliminary findings of this report, it appears feasible to use ERTS-1 data to monitor the extent and location of current strip mining activity for large regions and to evaluate the effectiveness of reclamation and pollution abatement procedures.

3. Surface areas affected by acid drainage from strip mines can be located and mapped effectively through careful digital processing of the ERTS-1 MSS data. They cannot be located from visual analysis of ERTS-1 imagery.

4. Temporal coverage of stripped areas spanning different seasons supplied by repeated ERTS-1 passes promises to provide even more powerful classification criteria because of the profound effects that strip mines and acid mine drainage have on vegetation.